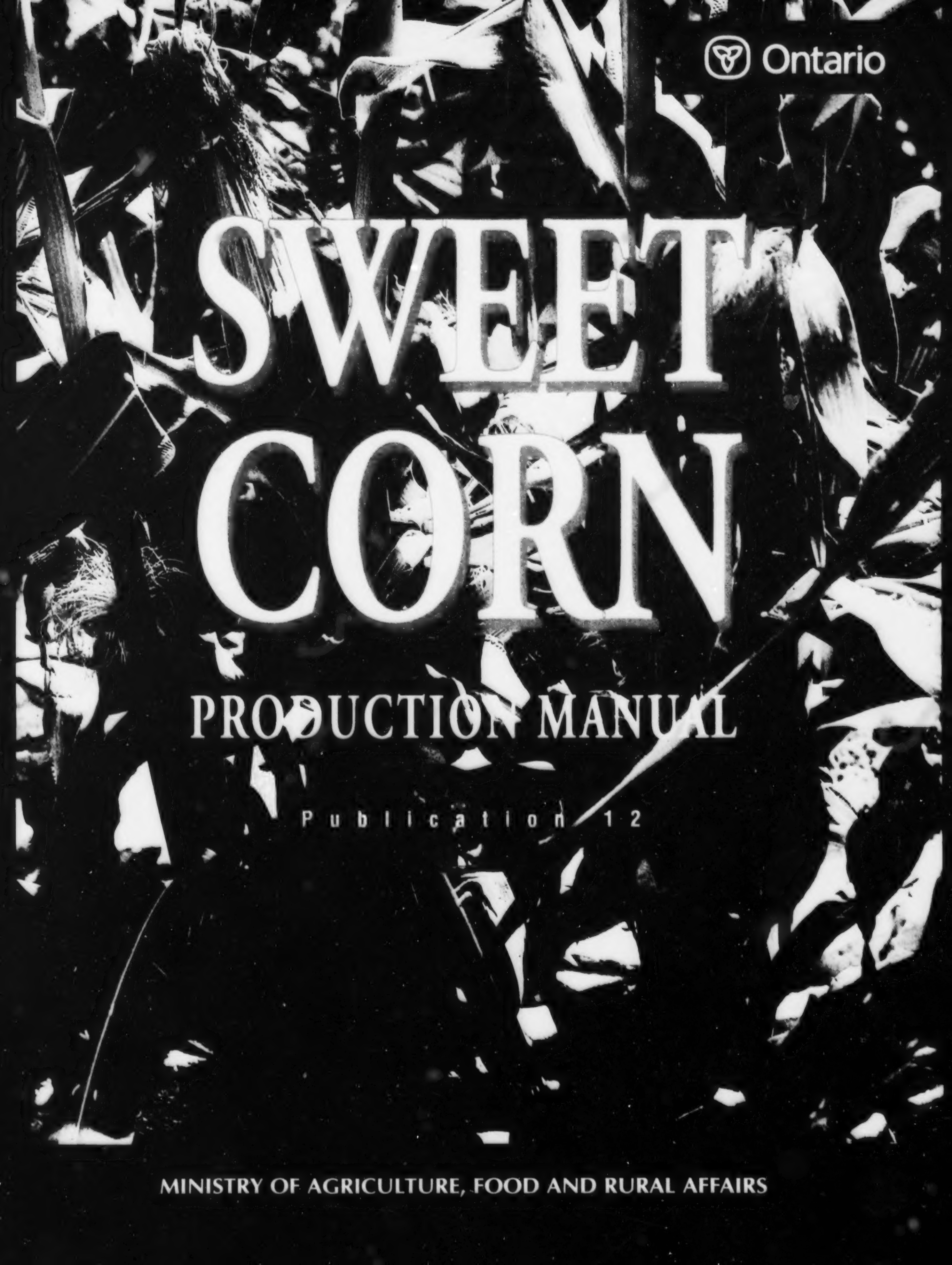

Ontario

SWEET CORN

PRODUCTION MANUAL

Publication 12

MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

Sweet Corn Production Manual
Publication 12

by Jody Bodnar and Paul Hagerman
Ontario Ministry of Agriculture, Food and Rural Affairs

Ontario Ministry of Agriculture, Food and Rural Affairs

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Contents

Tables

Figures

Plates

1. Principles and Practices

The principles involved with the production of sweet corn have not changed much over the last two thousand years. Our understanding of these principles has.

What principles most influence the growth and development of sweet corn and therefore are most responsible for making a profit?

Breeding of this crop has done more for the development of this industry than most anything else. However, once in the hands of growers, the variety has already been selected and therefore its influence genetically predetermined. It is the further growth and development of this "genetic blueprint" that this manual addresses.

A warm-season crop

During favourable conditions, sweet corn generally requires between 60 and 100 days to mature from seeding. This crop needs a soil temperature of at least 10°C (50°F) to germinate. Therefore, a 60-day corn may not mature until considerably later depending on its growing environment. In fact, the same variety of sweet corn can take from 2 to 20 days to germinate, depending on the soil temperature.

Frost injury normally occurs when temperatures dip to -2°C (28°F), but may recover if the growing point is still below ground. Corn up to 25 cm (10 in.), which is about the 6-leaf stage, usually recovers from frost. Taller corn is usually killed.

Sweet corn is classified as a C_4 crop, meaning that it is thermophilic or heat-loving. Not only does this crop respond to soil temperatures, it responds to the temperature of the air. Sweet corn often matures earlier than expected, especially if night-time temperatures are warm.

Sweet corn varieties

The sweet corn industry provides new and improved varieties each year, making it difficult for growers to keep up.

One of the problems is that there can be large variations within a variety (genotype) as it responds to its environment. Fructose, glucose, sucrose and total sugar concentrations, which determine sweetness, are influenced by the interaction between the variety and the environment. Total sugars have been reported to vary by as much as 24%. The location in which a variety is grown may account for only about 6% of the variation in total sugars. When the same variety is grown in different growing environments, the variation of total sugars may be as much as 65%.

The influx of new varieties also makes it difficult for growers to learn how to grow the same variety successfully, especially if its culture is weather dependent, which it usually is.

Normal sweet corn

Traditional cultivars contain the su gene. They have normal sugar levels and convert their sugar to starch quite quickly.

Sugar enhanced sweet corn

These contain the se gene. They have higher sugar levels and convert their sugar to starch. Because they have higher sugar levels to start with, they remain sweeter longer.

SE means that 100% of the kernals on each cob have enhanced sugar levels. In Se, only 25% of the kernels have the enhanced sugar levels.

Supersweet sweet corn

These contain the sh2 gene. They often have the highest sugar levels of all three types. They do not convert sugar to starch readily and therefore

stay sweet the longest. Cultivars with the sh2 gene tend to be more difficult to grow and crunchier to eat.

Sweet breeds—a new brand of sweet corn

The Harris-Moran seed company has recently introduced a line of sweet corn varieties with a unique set of genetics. Sweet Ice (white), formerly HMX 3356; Sweet Symphony (bicolour), formerly HMX 2349; and Sweet Rhythm (bicolour), formerly HMX 3354, have all three major gene types. These varieties are made up of 56% su, 22% se and 22% sh2.

These varieties are better able to germinate in cold soils because of the su gene. They carry the extended shelf life and sweetness associated with the su and sh2 genes, and the su gene is reported to impart that "old-fashioned" taste and texture. Sweet Breeds are also better adapted to machine harvesting, as they are less prone to bruising.

These varieties need to ripen fully before harvest to ensure maximum flavour and quality. Although the Sweet Breeds can become over-mature, they have a larger window of harvest opportunity than many other varieties. For purposes of isolation, these varieties should be treated as if they were an se.

For current OMAFRA sweet corn variety recommendations, see OMAFRA Publication 363 *Vegetable Production Recommendations*, Order No. 363.

Also see OMAFRA Factsheet *High Sugar Sweet Corn*, Order No. 90-126.

What about flavour?

If "beauty is in the eye of the beholder" then flavour is in the palate of the consumer.

There has been a lot of interest among plant breeders in ensuring they select for flavour when breeding new varieties. The sugar enhanced and super sweet varieties have come a long way in improved taste. And, consumers seem to be developing such a sophistication when buying from roadside stands, they ask for products by name.

When growers come to select varieties, does the choice come down to taste over yield potential, or does yield potential come first, with the hope that the taste will satisfy the client? If clients are well-enough known, varieties can be selected and grown for the client group.

Often, however, fruits and vegetables are not sold by variety, particularly in supermarkets. When a consumer finds something that tastes good, a repeat purchase often is not the same.

Crop rotations

Sweet corn should not be planted after field corn because of possible problems with corn rootworm, nematodes and Fusarium in the soil.

Sweet corn following vine crops may find an increased presence of corn rootworms. The western, southern and northern corn rootworm are pests of vine crops and are often found feeding on the blossoms. These same insects lay eggs in the soil to emerge the following summer to feed on the corn roots.

Where sweet corn follows legumes, the corn may require somewhat less nitrogen because of the large amounts left behind in the ground.

Sweet corn following cabbage or one of the brassicas can occasionally have foliage pale in colour. As cabbage breaks down in the soil, it acts as a mild fumigant and can cause reduced levels of nitrifying bacteria that temporarily suppress the availability of nitrogen. This is more evident in a dry year.

Since more herbicides can be used with corn than with almost any other crop, a corn rotation is a good way to clean a field of troublesome weeds.

Soil and nutrient considerations

Clay and loamy soils hold more water and are better suited to August and September production. Sandy soils drain better and warm up faster in the spring and therefore are better for early plantings.

Complete a soil test prior to planting. This will determine if additional phosphorus, potash, magnesium, manganese and zinc are needed. A soil test will also indicate the soil's pH and buffer pH. The amount of lime needed to increase the soil pH is

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calculated by the buffer pH. Sweet corn grows best in a soil pH range of 6.0–6.5. But it will tolerate pH levels as low as 5.5. The lime applied to raise the soil pH may take a year or more to have its full effect. The availability of many micronutrients, such as zinc and manganese, to sweet corn is reduced if the soil pH is greater than 7.0.

The recommended nitrogen rate is 90 kg/ha (90 lbs/ac). If manure is applied or legume sod ploughed down, reduce the nitrogen application. Adjusted nitrogen rates are available in OMAFRA Publication 363, *Guide to Vegetable Production Recommendations*, Order No. 363.

A portion of the required nitrogen and phosphorus should be applied at seeding either

- in a band 5 cm (2 in.) to the side and 5 cm (2 in.) below the seed. The rate of application in the band should not supply more than 75 kg N/ha (75 lb N/ac) or a total of 120 kg nitrogen plus postash per hectare in 75 cm rows (120 lb N plus potash/ac in 30 in. rows). If urea is the nitrogen source, no more than 40 kg nitrogen or 80 kg nitrogen plus potash per hectare should be applied in 75 cm rows (40 lb N or 80 lb N plus potash/ac in 30 in. rows), or
- in a band with the seed. With this placement no more than 9 kg nitrogen plus potash per hectare should be applied in 75 cm rows (9 lb N plus potash/ac in 30 in. rows). A major portion of the nitrogen should be pre-plant or side-dressed before the corn is 30 cm (12 in.) high.

Nitrogen fertilizers can increase soil acidity. The microbial conversion of the ammonium form of nitrogen to the nitrate form is an acidifying process. Adding large amounts of ammonium containing fertilizers can lower the soil pH, especially in sandy soils with low organic matter. The pH of sandy soils receiving ammonium, ammonia or urea forms of nitrogen fertilizers or manure should be monitored regularly with a soil test.

The germinating sweet corn seedlings need phosphorus early in the season. Cold soil in the spring can reduce the availability of phosphorus. Phosphorus is best banded at planting time. There may be little need for broadcast applications. Where excessive amounts of phosphorus have been applied, zinc may become unavailable to the crop. Apply only the recommended amount of phosphorus.

Some clay or clay loam soils are naturally high in potassium and may not require potash fertilizers. Use a soil test to determine the need for potash and the rate of application. If potash is needed, a major portion may be broadcast and worked into the soil in the fall or the spring prior to seeding.

A zinc soil test is helpful in determining the need for a zinc application. If zinc is required, it should be incorporated into the soil in a band with the nitrogen at the time of planting. No more than 4 kg/ha (4 lb/ac) should be banded at seeding. Zinc may also be applied as a foliar spray at a rate of 0.3–0.7 kg/ha in 300 L water (0.3–0.7 lb/ac in 66 gal water).

When sweet corn follows potatoes in a crop rotation, the soil pH may be low. If the soil pH is below 6.0, magnesium may be required. A magnesium soil test is helpful in determining the need for additional magnesium. If it is requred it can be applied as dolomitic lime.

Additional information on soil management and fertility is available in OMAFRA Publication 363, *Vegetable Production Recommendations*, Order No. 363 and Publication 611, *Soil Fertility Handbook*, Order No. 611.

Weed control

Weed control in sweet corn is usually based on a herbicide program and may be supplemented with inter-row tillage or hand hoeing. The list of registered herbicides for this crop is longer than for most vegetables. A wide selection of products can be used as pre-plant incorporated (ppi) or pre-emergence.

The number of products available for post-emergence weed control in sweet corn is considerably less than in field corn. Sweet corn varieties tend to vary greatly in their tolerance to certain herbicides. Phytotoxic reactions in specific varieties often prevent a product's registration in sweet corn. Variety-specific labels allow for these chemicals to be used only on varieties that have been proven tolerant.

Poor germination vigour

The newer sweet corn types that have the mutant endosperm gene shrunken-2 (sh2)—known as

For details on currently registered products, rates and the range of weeds controlled, refer to OMAFRA Publication 75, *Guide To Weed Control*, Order No. 75 or Publication 363, *Vegetable Production Recommendations*, Order No. 363.

supersweets—are very susceptible to seed rot and pre and post-emergent damping-off. These sh2's must be planted after soils have warmed up considerably or to some type of mulch.

The se's or sugar enhanced sweet corn types are not nearly as prone to the ill effects of cold soils, but are not as hardy as the more traditional su's.

At a soil temperature of 10°C (50°F) sweet corn germination is nearly at a standstill and it may take up to 20 days for the plants to emerge. The rate of germination is nearly twice as fast at 18°C (65°F) as at 13°C (55°F). Only 5–7 days are required at the higher soil temperature.

One of the main reasons for poor germination with the sh2's is that many of the seeds develop hairline cracks during the harvest process. They have a more fragile seed and are very susceptible to injury. These same cracks allow disease organisms to enter the seed during the harvest and delivery system and in the soil after planting. These seed cracks can be minimized by careful handling.

In addition, the sh2's have a low amount of endosperm (carbohydrate reserve) in comparison to the se's and su's, which reduces the seed vigour and germination capabilities. Internal membrane integrity is disrupted in sh2 seed, and this may cause some leakage of cellular sap. This in turn may be a substrate for mould growth and damping-off.

Because of the more fragile nature of the supersweets, growers are making more use of vacuum-type precision seeders (such as the Monosem and StanHay), which are easier on the seed. In addition, since sh2's vary more in size and shape, these vacuum seeders are better suited for singulation (separating seeds so that they are planted one-by-one).

Thermogradient tables

One of the more important characteristics of sweet corn seed, and one of practical importance to the grower, is how it performs on a thermogradient table. Yet this information, which should be available from seed dealers, is not widely publicized.

Using thermogradient tables, a grower can determine how a specific variety is apt to germinate in a range of soil temperatures. This information is most important when selecting varieties for cool soils and early markets.

Sweet corn populations

Most sweet corn is planted to a population of 45–50,000 plants per hectare (18–20,000 plants per acre). Most sweet corn is sold as having at least a 90% germination rate. Therefore, growers will usually plant at least 10% more seed than needed, hoping to achieve the desired plant population.

Early maturing varieties are generally smaller (shorter) plants and can be planted closer together. For example, 75 cm (30 in.) row spacings at either 20 or 23 cm (8 or 9 in.) within the row would give plant populations of 26,162 and 23,232, respectively. Alternatively, later (taller) varieties are often planted at 90 cm (38 in.) row centres, and at either 23 or 25 cm (9 or 10 in.) between plants, the plant populations would be 18,379 and 16,500.

Tip fill

When it comes to marketing, it is paramount that there be good tip fill. Husk colour, length of flag, cob size, row count, etc., although important, do not sell if tip fill is poor. As plant populations increase after a critical point, the amount of poor tip fill also increases to the point where there can be barren stalks.

Double-eared hybrids

Lower plant populations may benefit hybrids that produce double ears. However, this type of corn is not suitable for machine-harvesting and presents problems even when handpicking. Invariably, where there are two ears per stalk, one is ready to harvest before the other. This situation has been alleviated somewhat with the sh2's because of their holding capacity on the stalk. Most seed companies are now breeding for only one ear per plant.

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Lower plant populations may benefit hybrids that produce double ears. However, this type of corn is not suitable for machine-harvesting and presents problems even when handpicking. Invariably, where there are two ears per stalk, one is ready to harvest before the other. This situation has been alleviated somewhat with the sh2's because of their holding capacity on the stalk. Most seed companies are now breeding for only one ear per plant.

Early vs late harvest dates
Theoretically, time of harvest can determine how to gauge plant densities. However, this may be more a philosophical approach than a scientific one. For example, very early plantings would be expected to have a greater plant loss because of the stresses of cold soils and growing conditions. Should sweet corn planting density be increased to compensate for these losses or should it be reduced to minimize the loss?

Similarly, late plantings should ideally give 100% plant stands. However, corn ripening in the late fall tends to have a smaller ear size, and this can be aggravated by crowding.

Carry-over seed
Whether to plant carry-over seed late or early seems to be an area of preference. Late plantings are easier on the seed. However, if germination has fallen off, some growers plant early since there are going to be losses anyway, and whatever survives is a bonus. Some seeds store satisfactorily for several years. However, corn is best stored for no more than a year. Otherwise, the per cent germination and vigour may decrease dramatically.

Tillering
Early planted corn is more prone to tillering, and this can make the crop more difficult to manage. There are bound to be more tip fill problems with early plantings.

Transplanted corn is also more prone to tillering. This is thought to be a response to cold temperatures experienced at transplanting.

Fertilizer and moisture
Higher populations of corn suggest a greater demand for soil nutrients and therefore a higher rate of nitrogen. Moisture stress may be more prevalent in dry years with higher plant populations, especially on certain soil types. These nutrients and soil moisture supply are critical in achieving maximum tip fill.

When to disc under
As a general guideline, where there is less than a 70% plant stand, the cost of going ahead with the culture and harvest of this crop will likely lead to little or no net return. This is especially true if the stand is non-uniform in growth and development.

Factors against discing under are availability of seed, timing of market commitments, continuity of customer supply and replanting costs.

Scheduling sweet corn
This is perhaps one of the most difficult things to accomplish in sweet corn production. Having to bypass corn because of bunching-up of harvest dates is dispiriting.

Perhaps the most accurate method is the use of corn heat unit (CHU) accumulations. This method takes into account the high and low temperatures recorded each day.

Keep in mind that the germination differs between seeds even though seeds are from the same variety. At a planting population of 55,000/ha (22,000/ac), there are about the same number of micro-environments for each seed to encounter. This gives rise to a greater or lesser degree of uniformity throughout the field.

Planting the same variety in succession where possible helps supply a consistent product and flavour.

At times, growers try to fit in a late season crop by planting a short days-to-harvest variety, such as Earlivee, during the last days of August. Although these varieties germinate, they tend not to grow or yield very well during the shorter days of summer. This strategy should be avoided

Transplanting sweet corn
The idea of transplanting corn with the goal of hastening maturity is not new.

Work conducted in Tennessee in 1989 found that transplanting increased earliness of harvest depending on the type of container in which it was grown.

Container Type	*Harvest Date*
Peat pot	June 5
Peat pellet	June 9
Seedling tray	June 12
Direct seeded	June 25

Production costs of transplants may be prohibitive for large plantings. However, market gardeners may find it economical on a small scale, as such early crops can be used as marketing and advertising tools for the main-season crop.

During transplanting, the roots may be damaged to such an extent that plant development becomes uneven and does not allow for once-over harvesting.

There have also been attempts to grow corn in greenhouses. This has proven to be counter-productive, as plants tend to come into tassel very quickly and yield poorly.

Pollination requirements

Cross-pollination between incompatible varieties can have a dramatic effect on the quality of the crop. For a variety to reach its full potential, it must grow in isolation from any incompatible gene type.

Pollen from field corn makes all types of sweet corn starchy. Sh2 varieties must be separated from su's and se's as cross-pollination will make the kernels starchy. Pollen from su varieties will not turn the se's starchy. However, it will decrease the sugar content to that of a normal su. To maintain high quality, isolate su and se varieties.

The colour of a variety can influence the colour of other varieties. Yellow is the dominant gene. Pollen from a yellow or a bi-colour variety causes some yellow kernels in pure white varieties.

Separate incompatible varieties by at least 100 m (350 ft). This distance should be increased where prevailing winds may carry the pollen farther. Scheduling plantings so that tasselling times are 2 weeks apart may also achieve isolation.

More information on pollination and isolation of sweet corn can be found in the OMAFRA Factsheet *High Sugar Sweet Corn*, Order No. 90-126

When to harvest

Days-to-harvest is the general guideline used and is supplied by seed companies. This often proves to be ineffective as corn is affected mostly by heat. Excessive periods of heat can prove to be very challenging in getting corn harvested and to market.

The use of corn heat units (CHUs) is widely used in the field or grain corn industry and would probably be more reliable to growers in the fresh market business if it were more available.

Otherwise, as a rule of thumb, sweet corn is ready to harvest 18–21 days from 50% silk, 16–18 days from 100% silk, or 10-12 days from 100% brown silk.

Since se and sh2 varieties are delayed in the transformation of sugar, these gene types can "hold" on the plant for a short while. Even though the supersweets have a wider harvest window than either the su's or se's, this advantage should not be abused, and corn should be harvested as soon as the variety reaches its maximum quality.

Ordinarily, su and se types need to be harvested within 24–48 hours of becoming mature for maximum quality while the sh2's can remain in the field for an extra 1–3 days, depending on the weather.

Removing tassels and suckers

Neither detasselling nor suckering has been shown to give much advantage in advancing the maturity date or increasing the quality of the ears.

The tassel is required to pollinate the silks. Even if the tassels are removed after silking and pollination, it has not been found to increase yields. In fact, removing the tassel removes some of the carbohydrate manufacturing capacity important to ear development. Detasselling may allow for easier viewing of ears at harvest time. If this is the reason, it should be done only a day or two before harvest.

Leaving tassels on corn provides a flag to indicate European corn borer injury. This pest often travels to the tassel first. In most cases, the tassel falls over before the larvae emerge from the feeding place and travel down the outside of the stalk to the tip of the ear. Please note, however, that this is not a reliable indicator of corn borer infestation.

Although certain varieties tend to sucker profusely, this characteristic does not hinder the genetic capacity to develop to its fullest potential. Removing the suckers from plants may result in the development of smut.

Often, those varieties having a tendency to sucker will produce more than one usable cob. In fact, at wider plant spacing and during good growing sea-

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Although certain varieties tend to sucker profusely, this characteristic does not hinder the genetic capacity to develop to its fullest potential. Removing the suckers from plants may result in the development of smut.

Often, those varieties having a tendency to sucker will produce more than one usable cob. In fact, at wider plant spacing and during good growing sea-

7

sons, vigorous plants produce 3 usable ears. The second and third ears are somewhat smaller and ripen 2–3 days later. This limits the benefit to the commercial grower.

Demand for full ears

Buyers and distributors have developed a knack for pointing out deliveries of corn with poor tip fill. It can be caused by varietal differences. Poor tip fill is difficult for growers to control.

Poor tip fill is largely due to drought stress during the filling period. Short of irrigating, the grower should select varieties known for good tip fill. Poor tip fill can be due to excessively hot weather, which causes the pollen to denature, or hot drying winds, which desiccate the silks so that they are no longer receptive to pollen. Silks may also be clipped by insects such as corn rootworms.

Periods of extreme drought may prevent the filling of individual kernels even though they were adequately fertilized.

A few days after the tassel is fully expanded, the anthers (male flowers) are thrust out and pollen shedding begins that may continue for 7–10 days. Often this period is associated with a sweet fragrance in the crop caused by this pollen.

The silks begin to emerge from the ear 1–4 days after the pollen begins to shed. Fertilization of the ovules that develop into kernels begins about a third of the way up from the base of the ear and extends in both directions.

Weather conditions during this short period of fertiiization and kernel development are crucial. This is the time when the physiological mechanisms within the plant adjust the size of the kernel to the likely capability to produce the mature grain, although in the case of sweet corn the ears will be harvested at an immature stage.

Factors leading to reduced ear lengths likely include high plant populations, weed competition, moisture stress, a shortage of nutrients, or several days of low light.

Where irrigation is possible, the period immediately before and after pollination is the key time to supply water. Once the kernels are set, their numbers cannot be increased; only their size can be influenced.

Yield potential

Sweet corn yields can vary considerably, depending on the variety, time of harvest and year of planting. The wholesale sweet corn industry uses bags or crates holding 5 dozen ears as the standard unit. Wholesale yields range from 500– 750 bags per hectare (200–300 bags per acre).

For the roadside and retail market, 2,500 dozen per hectare (1,000 dozen per acre) is a good target yield. Under excellent management yields can exceed 3,000–3,700 dozen per hectare (1,200–1,500 dozen per acre).

At the higher yield range, some of the plants will have more than one ear. However, most varieties are bred for one good marketable ear per plant.

One of the biggest problems contributing to loss of yield is barren stalks or plants with no ear development. This is generally due to too-close plant spacing. Most varieties are planted 20–31 cm (8–12 in.) apart within the row. Where corn emerges at 15–18 cm (6–7 in.) apart, there is a good chance the plants will be barren. This can be a problem when corn is deliberately over-planted to compensate for poor germination.

Tables 1 and 2 on pages 8 and 9 show the potential yield and net return, both wholesale and retail.

Hydrocooling and storage

Hydrocooling is the best way to remove field heat from sweet corn. However, if the corn is to be sold retail the day of harvest, cooling may not be necessary. Corn should be cooled to below 5°C (40°F) as soon as possible.

The half-cooling time for corn in husks is 20 minutes. This means that where sweet corn is immersed in 0°C (32°F) water, half the difference between the water and ear temperature is reached in 20 minutes. For example, corn at 30°C will be reduced to 15°C in 20 minutes, and a further 7.5°C in another 20 minutes to a temperature of 7.5°C.

Corn should be stored below 5°C (40°F) where possible, and ideally at 0°C with 98% relative humidity. Otherwise, circulate the air in the storage room and stack bins for maximum surface area exposure.

Table 1. Sweet corn (roadside and retail): Potential yield and net return
All figures based on 0.4 ha (ac)

Seeding rate	% Marketable yield	Yield	Price per dozen	Gross income	Net income
			$2.00	$1800	$900
	60%	900 doz	2.50	2250	1350
			3.00	2700	1800
			2.00	2100	1050
18,000	70%	1050 doz	2.50	2625	1575
			3.00	3150	2100
			2.00	2400	1200
	80%	1200 doz	2.50	3000	1800
			3.50	3600	2400
			2.00	2000	1000
	60%	1000 doz	2.50	2500	1500
			3.00	3000	2000
			2.00	2332	1166
20,000	70%	1166 doz	2.50	2915	1749
			3.00	3498	2332
			2.00	2666	1333
	80%	1333 doz	2.50	3332	1999
			3.00	3999	2666
			2.00	2200	1100
	60%	1100 doz	2.50	2750	1650
			3.00	3300	2200
			2.00	2566	1283
22,000	70%	1283 doz	2.50	3208	1925
			3.00	3849	2566
			2.00	2932	1466
	80%	1466 doz	2.50	3665	2199
			3.00	4398	2832
Net: Assuming cost of production @ $1.00/doz. Note: @ $2.00/doz ($0.17/ear); @ $2.50/doz ($0.21/ear);@ $3.00/doz ($0.25/ear).					

The supersweets can generally be stored for up to 2 weeks — thus their popularity with supermarkets. Their flag leaves and husk colour begin to fade much the same as the su's and se's if not stored properly.

For more information on harvesting and cooling contact the Ontario Farm Fresh Marketing Association (Grimsby, Ontario, 905-945-9057). In 1994, this organization produced a video and handbook with details of an economic comparison of several methods of harvesting and cooling sweet corn.

Table 2. Sweet corn (wholesale): Potential yield and net return
All figures based on 0.4 ha (ac)

Seeding rate	% Marketable yield	Yield/ac (5 doz/bag)	Price per bag	Gross income	Net income
			$6.00	$900	$(37)
	50%	150 bags	7.00	1050	113
			8.00	1200	263
			6.00	1080	(45)
18,000	60%	180 bags	7.00	1260	135
			8.00	1440	315
			6.00	1260	(52)
	70%	210 bags	7.00	1470	158
			8.00	1680	368
			6.00	996	(41)
	50%	166 bags	7.00	1162	125
			8.00	1328	291
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20,000	60%	200 bags	7.00	1400	150
			8.00	1600	350
			6.00	1398	(58)
	70%	233 bags	7.00	1631	381
			8.00	1864	614
			6.00	1098	(45)
	50%	183 bags	7.00	1281	138
			8.00	1464	321
			6.00	1320	(55)
22,000	60%	220 bags	7.00	1540	165
			8.00	1760	385
			6.00	1536	(64)
	70%	256 bags	7.00	1792	192
			8.00	2048	448

Net: Assuming cost of production @ $1.25/doz. Note: @ $6.00/bag ($0.10/ear); @ $7.00/bag ($0.115/ear); @ $8.00/bag ($0.13/ear). Note: One green mesh bag usually holds 5 doz. or 60 ears.

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2. Plastic Mulch and Row Covers

Ordinarily, heat is accepted as having the greatest influence on all biological processes. Therefore, it is useful to know when this influence becomes critical in the growth and development of corn, and how it can be controlled.

Mulching is one of the best ways to manage heat. Clear plastic mulch acts much like a greenhouse and results in the warming of soils. While mulching cannot be guaranteed to result in economic gain in all years, it is fast becoming an essential practice for early market sales.

The main reason for using plastic mulch or row covers is earliness. It can increase the marketing season and allow product to be sold at a premium. Plastic mulch often results in increased yields and better product quality. This is accomplished primarily by warming the soil and creating a cleaner environment. It creates an early summer, and this allows for the maximum genetic expression and potential of any one variety.

Systems approach

Because of its costs, plastic mulch should be thought of as part of a complete growing system. Every effort must be made to recoup this cost. This can be done by

- choosing early land
- choosing early, suitable varieties
- using the plastic properly
- ensuring proper soil pH, soil drainage and moisture, and crop rotation.

Insurance against a cold spring

Plastic mulch provides maximum benefits during unreasonably cool springs or when planting earlier than normal using conventional methods. A 7–14 day advantage may result under these conditions. If the season turns out to be unseasonably warm, there may be no gain. Using plastic mulch is insurance against a cold spring and a strategy for securing early, lucrative markets.

Soil temperatures critical

The minimum soil temperature required for germination depends on the type of cultivar. For example, su varieties require 13°C (56°F), se's 16°C (61°F) and sh2's require 18°C (65°F). All varieties germinate much faster in warmer soils.

Soil moisture conditions and air temperature also affect early growth and development.

Yield

An average of 2,400 dozen ears of corn per hectare (1,000 dozen per acre) is an enviable yearly yield. However, with the use of plastic mulch or row covers, yields upward of 3,000–3,750 dozen per hectare (1,200–1,500 dozen per acre) should be within reach. Under exceptional conditions, 5,000 dozen (2,000 dozen) may be achieved.

The extra yields result from increased plant stand caused by better germination and from more even maturing, which means fewer ears are left in the field. Most farmers grow one-eared varieties. However, where two-eared varieties are used, a greater percentage of plants mature both ears for a simultaneous harvest.

Keep in mind that when using a plant population of 20,000, which yields 1,666 dozen or 333 bags under perfect conditions, a 10% decrease in plant stand means a loss of 2,000 plants or 166 dozen (33 bags).

As yields are part-and-parcel of planting densities and earlier maturing varieties are normally smaller than main season varieties, the in-row spacing should be adjusted downward, 20–25 cm (8–10 in.)

apart. However, where corn is deliberately overplanted to compensate for poor germination, the closeness of plants often results in barren stalks.

Better quality

Using plastic mulch results in more uniform soil conditions throughout the growth cycle. Better availability of nutrients and moisture at the time of tasselling, silking and ear-fill allow for optimum production. The plant is less likely to suffer from stress. As a result, ear size is often increased by 10%–20%.

Corn grown to plastic is more robust and taller, resulting in higher ear placement on the plant, 15–30 cm (6-12 in.) higher, making it easier to harvest.

Tricks of the trade

Heavier mulches are usually easier to remove as they are not as apt to tear. These mulches are usually 0.9 mil in thickness.

Mulch should be laid up to 2 weeks in advance of planting to ensure adequate warming of the soil. Although soil can warm up quickly when using mulch under sunny conditions, prolonged overcast weather delays the process significantly.

Do not lay mulch on dry soils as these will be slower to warm and prevent rapid germination. Water is a better transmitter (conductor) of heat than air, and it also retains heat longer (more insulating value).

Plastic will stretch better if warmed prior to use. This can be done by storing it in a heated barn or by setting it out in the sun. Plastic that is laid cold stretches once warmed by the sun, causing it to ripple and be more prone to wind injury.

Orient the rows so that they are aligned with the prevailing wind to minimize the lifting of plastic if it becomes loose around the edges.

For quicker germination, seed to a shallow depth of 12 mm (0.5 in.) where soil is warmest.

Use sized seed, as larger seed germinate faster. The difference in seed count of 6,600 seeds/kg (3,000 seeds/lb) versus 11,000 seeds/kg (5,000 seeds/lb) can result in a 4–5 day advantage in germination.

Options

Clear plastic mulch, infra-red transmitting mulch and floating row covers are all used in sweet corn. Heavier row covers may be used for frost protection on small areas. Realistically, only a 2–3 C° (3–5F°) level of frost protection will be achieved.

Clear plastic mulch

Clear plastic mulches transmit solar radiation directly to the soil surface. Heat loss from the soil is prevented by the accumulation of condensation on the under surface of the mulch. The water droplets block the escape of long wave radiation. Daytime soil temperatures are generally 4–8C° (7–14F°) warmer than bare soils at the 5 cm (2 in.) depth. At the 10 cm (4 in.) depth, temperatures are generally 3–5C° (5–9F°) warmer. Weed control under clear plastic is often challenging.

Infra-red transmitting mulch (IRT)

IRT plastic mulches absorb the range of light used in photosynthesis, thereby preventing weed growth. But the level of soil warming is not quite as high as with clear plastic.

Floating row cover (spunbonded)

This is an exaggerated row cover that covers many rows at once and can be left on for an extended period, with the crop lifting the cover as required. The row cover can be left on quite safely until the plants are 30 cm (12 in.) high, as the material will bubble up at the centre without needing any extra slack, although the outermost rows may be restricted. In some cases this row cover is left on until tasselling. However, once temperatures reach 32°C (90°F), the cover should be removed. Row cover materials are generally saved and reused for a second or third year, reducing the cost considerably.

Transplants

Transplants have been used for many years to gain earlier markets. Best results are obtained from 2 to 3-week-old plants that are grown in deep-celled trays (72 to 98 cells) allowing for a

larger root system. Since corn grows so quickly, 4-week-old plants are getting almost too large to handle without injury. Transplants between 17 and 21 days are best. If poor weather prevents planting, they may become too big to handle.

Direct seeding

Direct seeding can be done using a variety of equipment. Vacuum seeders are gaining in popularity because of their ability to singulate seed and use seed that is irregular in shape or variable in size without the risk of cracking seedcoats.

The polyplanter, which consists of a mulch layer and vacuum seeder unit, can lay the plastic, make the holes and drop the seed all in one operation.

For sweet corn, the plastic mulch is most often laid on a 1.5 m (60 in.) centre, with two rows of corn [about 60–70 cm (24–28 in.) between rows] on each mulch strip. At 20 cm (8 in.) between seeds on this between-row spacing, the seeding rate is about 64,000 seeds/hectare (26,000 seeds/acre).

Varieties

Traditionally, the earliest season varieties were the su type because of their good cold-soil tolerance and germination characteristics. Newer genetics have allowed for better varieties to be planted for the earlier markets, especially when using a mulching system.

With se bicolours dominating the marketplace, many growers are using mulch to bring them to market sooner. The Sweet Breeds have triple genetic gene combinations comprising su, se and sh2 characteristics allowing for early maturation while allowing for flavour and "holdability."

The SE group can be classified as homozygous, meaning they have the se gene from both parents. Consequently, their germination is not as vigorous as the heterozygous Se's. These latter varieties result from the cross between a homozygous se and an su. Thus, the germination behaves more like that of an su. Only 25% of the kernels of a heterozygous variety are se, and therefore these varieties are not as sweet.

The first main factor to consider is the days-to-maturity of a variety. The aim is to get good quality corn to the marketplace early, and in volume if possible. Therefore it is prudent to choose short-season varieties to complement the advantages of mulch. Varieties should fall into the 65–75 day maturity range with the emphasis on the early end.

Weed control

Herbicides are generally applied to the entire field before laying the mulch. However, some equipment allows for the banding of herbicides just prior to laying the mulch.

Most of the broadleaf weeds are cooked and killed under a hot plastic mulch under very sunny conditions. However, this is not a reliable method of weed control as not all weeds are prone to heat stress.

Atrazine, Bladex and Dual are the three main herbicides used under clear plastic mulch. Their use depends somewhat on the crop rotation. The high rate of Dual should be used to ensure good grass control. This is especially important where fall-panicum is a problem. Sweet corn does not grow as fast or as large as field corn and therefore does not shade the ground as much, allowing for increased chance of the late season germination of fall-panicum. As well, none of these herbicides controls atrazine-resistant lamb's quarters.

These three herbicides are best pre-plant incorporated, allowing for better contact with the weed seeds. If herbicides are applied pre-emergence with no rain to move the weed control into the soil, their effectiveness may be reduced.

Occasionally, herbicides volatilize and "funnel" out through the hole, causing some plant injury. In other cases, where herbicides have been banded beneath the mulch only, and with Gramoxone or Round-up used between the rows, these herbicides can wash into the holes in the plastic and cause crop injury. This risk can be minimized by directing spray away from the plastic or by waiting for a rain

M121

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to wash off the herbicide from the plastic prior to seeding or transplanting.

Herbicide labels generally do not mention the use of plastic mulches unless the use is not allowed or precautions are necessary. Unless the label specifies otherwise, herbicides can be used in combination with plasticulture as long as all label directions are followed, including herbicide rate, placement, timing and crop planted.

Fertilizers

With the use of plastic, there is no opportunity to sidedress. All of the fertility requirements need to be broadcast-incorporated. In some instances, banding of fertilizer can be done with the laying of mulch.

Nitrogen is the one nutrient having the most influence on growth, yield and quality of sweet corn. About 90 kg/ha (90 lbs/ac) of ammonium nitrate adequately brings the crop to harvest.

Other advantages of plastic mulch

Increased soil moisture content

Where mulches are laid early in the season while soil moisture levels are high, the soils remain moist until time of seeding, even if dry weather prevails.

Reduced evaporation

Because of the nature of plastic mulch, moisture and water vapour are conserved within the soil.

Reduction in loss of fertilizer

Excess water runs off the plastic mulch into the aisleway, reducing the amount of fertilizer lost to leaching. Thus, plastic helps retain the nutrient level around the rooting zone, allowing for more uninterrupted growth.

Higher levels of carbon dioxide

Plants give off oxygen and take in carbon dioxide necessary for growth and development. Plastic mulches, tunnels and row covers help create increased levels of CO_2 by preventing or slowing down its escape, thereby creating an enriched gaseous environment—at least temporarily.

Reduction in waterlogging

Water is shed from the bed preventing the drowning of seeds and seedlings and other excess soil-water stresses.

Frost protection

The plastic mulch may offer some protection from frost. Corn is injured at -2°C (29°F), but usually recovers when young, since the growing point is still below ground up to about the six-leaf stage.

Ease of harvest

Harvesting can be easier since the ears are usually located 15–30 cm (6–12 in.) higher on the plants. This is particularly important for mechanical harvesters, which sometimes miss ears because they are too close to the ground, especially for early maturing varieties.

Root pruning

Root pruning is eliminated since sidedressing and tillage are not used to apply additional fertilizers. This is particularly important to sweet corn as it is more shallow-rooted than field corn.

Flea beetles

These insects can be excluded with the use of floating row covers until corn is large enough to withstand feeding injury or the transmission of diseases.

Sand blasting

This can largely be eliminated with the use of mulch and stale seedbed techniques.

Soil crusting

This is eliminated if plastic is laid in advance of pounding rains followed by excessive drying conditions.

Disadvantages

Non-selective

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growth of any weed escapes not controlled by herbicides.

Economics

If the cost of plastic mulch is about $563/hectare ($225/acre), and if early corn gets $15/bag, a total of 15 bags is required to offset the cost of the plastic mulch.

1.0 mil plastic (clear or black) retails for about $100 per 1,219 m x 122 cm (4,000 ft x 48 in.) roll. When using it at a 1.5 m (5 ft) row centre, there are 6,667 m of row per hectare (8,712 ft per ac). Prices are for 1999.

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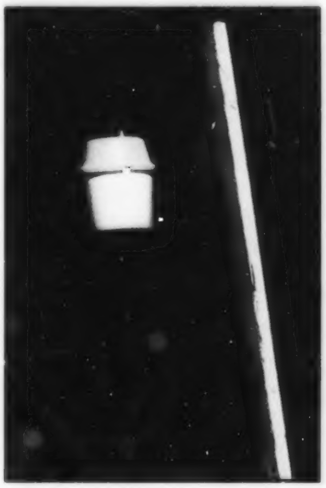
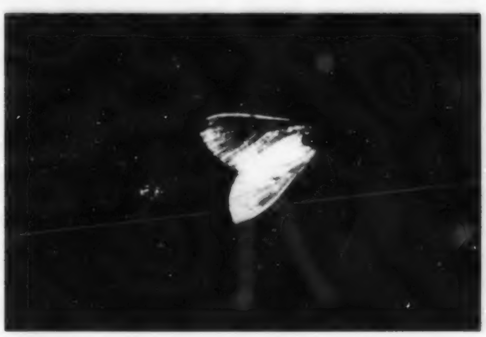
1 Heliothis trap for corn borer or corn earworm

2 Unitrap for fall armyworm



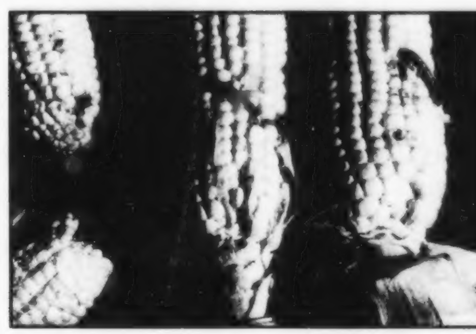
3 European corn borer moths — male is smaller and darker than female



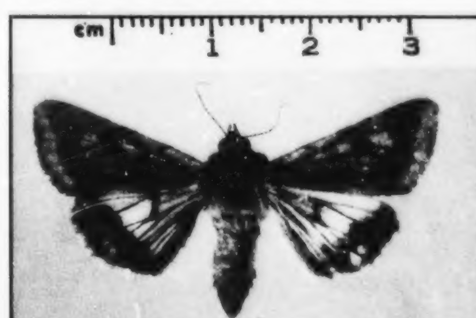
4 European corn borer eggs — white eggs are freshly laid; eggs with black centres hatch within 1 day

5 European corn borer larva

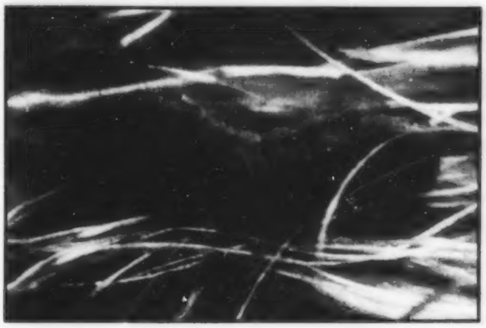
6 Corn borer damage



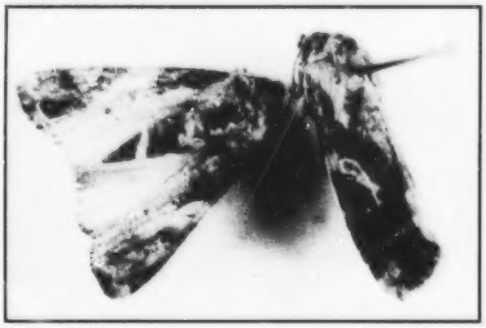
7 Corn earworm moth



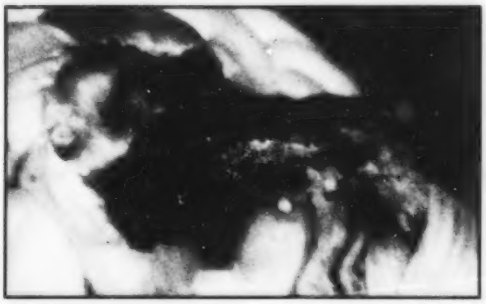
8 Corn earworm larva — note tan-coloured head



9 Fall armyworm moth — note white slash on forewing



10 Fall armyworm larva — note inverted "Y" on face

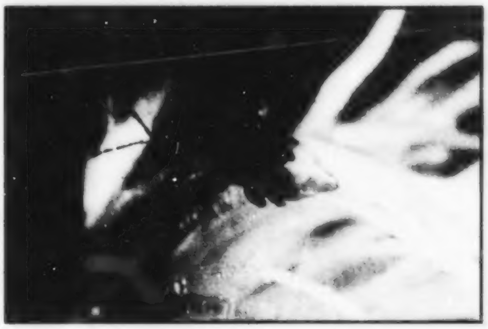


11 Fall armyworm damage

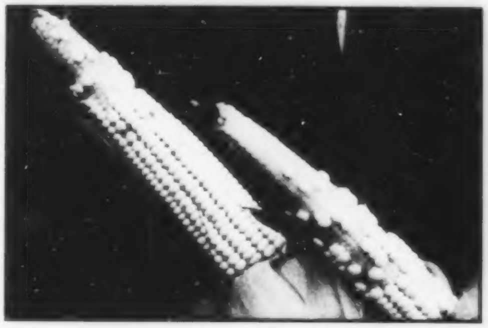
12 Corn leaf aphids

13 Northern corn rootworm

14 Western corn rootworm



15 Barren ear from rootworm beetle feeding

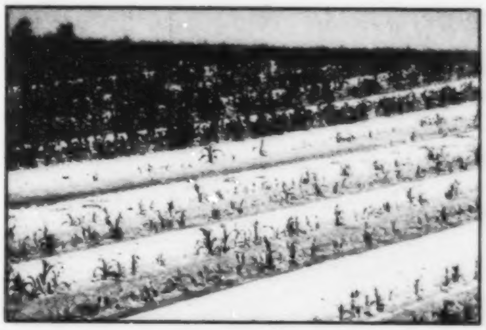


16 Potato stem borer/hop vine borer damage

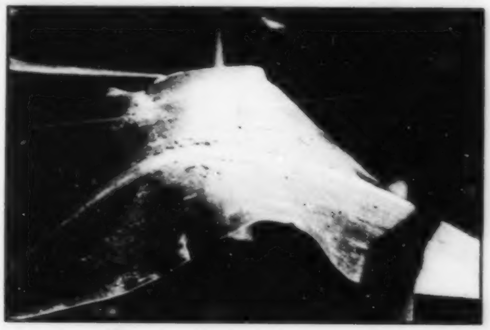
17 Black cutworm and damaged corn plant

18 Corn flea beetle damage

19 3–5 leaf dieback



20 Common rust

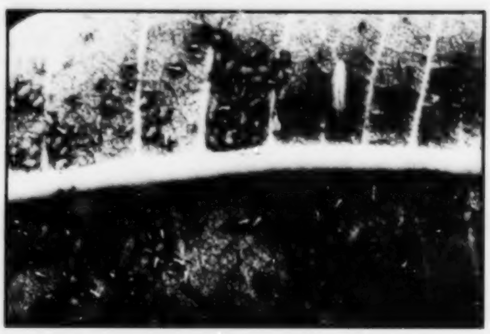


21 Common smut

22 Stewart's wilt

23 Bird damage

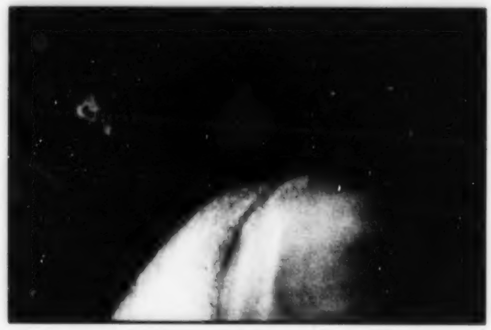
24 Hoverfly larva feeding on aphids



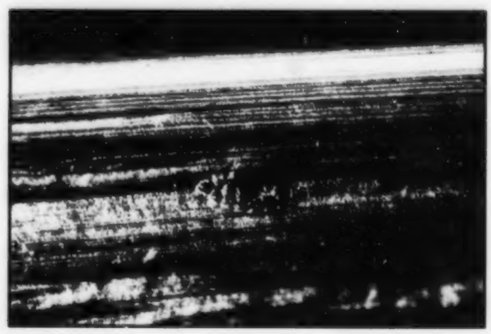
25 Lacewing larva

26 Ladybeetle larva

27 Minute pirate bug



28 Parasitized corn borer eggs



3. Pest Management

Integrated pest management (IPM) incorporates all control measures (chemical, biological, cultural, etc.) to minimize the impact of pests on a crop and the impact of the crop on the environment.

Integrated pest management can

- delay or prevent pests from developing resistance to pesticides
- result in reduced levels of pest damage
- save growers money by reducing the number of sprays applied
- reduce the impact of pesticides on the environment.

Table 3 lists IPM techniques and their effects.

Table 3. IPM techniques used in sweet corn

Technique	Targeted pests	Desired effect
Pheromone traps for insect pests	ECB, CEW, FAW	better timing of field scouting or controls
Field scouting	all insects and diseases	determine need and best timing for controls, based on action thresholds
Pesticide sprays	all insects and diseases	reduce or eliminate damage
Choice of pesticide	all pests	select pesticides based on efficacy, longevity, impact on beneficials, days-to-harvest interval
Transgenic Bt* corn	ECB, CEW, FAW	controls insects without spraying
Biological control—naturally present beneficials	most insects, with greatest impact on aphids	reduce pest damage without insecticides
Biological control—beneficials bought for release	beneficials available for many pests, but ECB most common targeted	reduce pest damage without insecticides
Choice of variety	aphids, flea beetles, all diseases	select varieties that suffer less damage from insects or diseases
Seed treatment	3–5 leaf dieback, early season insects	improve plant stand
Timely harvesting	sap beetles, vertebrate pests, CEW	reduce late season losses
Crop rotation	corn rootworm	prevent root feeding damage
Harvest assessment	all insects and diseases.	assess level of damage and how well control program worked

* *Bacillus thuringiensis*

Pest abbreviations: ECB - European corn borer
CEW - corn earworm
FAW - fall armyworm

Pests that attack sweet corn

Several types of insect, fungi, bacteria, viruses and animals can damage sweet corn. The most serious pests are three species of caterpillars, which are compared in Table 4. *Worms feeding in sweet corn*. European corn borers cause the greatest loss, as they cause damage through the entire season. The other two, corn earworms and fall armyworms, usually arrive in August and can cause considerable damage later in the season. Even with the use of integrated pest management, most fields need insecticide sprays to keep caterpillar damage within tolerable limits.

Table 4. Worms feeding in sweet corn

	European Corn Borer	Fall Armyworm	Corn Earworm
Body colour	spotted dirty pinkish-white with dark spots; pale strips may also be visible	striped greyish or brownish with distinct stripes	striped yellowish, greenish or brownish, with distinct stripes
Head colour	medium to dark brown	dark brown to black, with an obvious white inverted "Y"	tan-coloured; an inconspicuous "Y" is sometimes visible
Length of full-grown larva	2.5 cm (1 in.)	3.7 cm (1.5 in.)	3.7 cm (1.5 in.)
Mid-dorsal line (stripe down centre of back)	none	single wide line	double fine lines
Proleg hooks ("Claws" on legs in middle of body—use a 10X lens)	hooks form a circle or nearly complete circle	hooks from a straight line, arc or half circle	hooks form a straight line, arc or half circle
Feeding location	anywhere on plant	extensive feeding on leaves; usually enter ear through the side	almost exclusively in the ear tip zone, entering through the silk channel

Table 5. *Sweet Corn IPM Flow Chart* explains how to make decisions on control of these caterpillars using information from insect traps and field scouting. For example, when early corn is tasselling, the only caterpillar pest to worry about is the European corn borer, which should be controlled if it is present on 5% or more of the plants. For any corn in silk, the corn earworm becomes a priority. If earworms are present, field scouting is no longer effective. Instead, sprays are timed according to trap counts and daily temperatures.

Table 5. Sweet corn IPM flow chart

Growth stage	Early plantings (harvest in July)	Mid-season and late plantings
Early to mid-whorl corn	no action	Check traps for fall armyworm absent no action present scout for FAW damage in field <15% no action >15% spray
Late whorl and tasselling corn	Check traps for European corn borer absent no action present scout for ECB damage in field <5% no action scout again in 4 days >5% spray scout again in 7 days	Scout for ECB and FAW damage in field <5% no action scout again in 4 days >5% spray scout again in 7 days
Silking corn	Check traps for corn earworm absent Scout for ECB and FAW damage in field <5% no action scout again in 4 days >5% spray scout again in 7 days	present Spray ear zone every 3–7 days depending on maximum daily temperature and CEW moths/trap/week

moths	<27°C	>27°C
1–6	5–7 days	5–7 days
7–90	5 days	4 days
>90	4 days	3 days

Several other insect pests attack sweet corn. In some cases, they may need to be controlled with insecticides, but usually they can be kept below damaging levels with cultural controls and natural biological control in the field.

Diseases usually do not cause as much loss as insects in sweet corn, but they can be serious. Most important is 3–5 leaf dieback, which affects the plants shortly after emergence and can lead to very poor stands. Table 6. *Sweet corn pest monitoring guide* outlines when diseases and insect pests are likely to be present, how to monitor for them, and when to take action.

Table 6. Sweet corn pest monitoring guide

Early plantings Mid-season plantings Late plantings	seed whorl tassel silk harvest seed whorl tassel silk harvest seed whorl tassel silk harvest							Monitoring method	Action threshold
	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT		
Diseases 3–5 leaf dieback								general observation	none
Common smut								general observation	none
Corn rust								general observation	rust visible on leaves before tassels emerge
Insects Seed corn maggot, cutworm, potato stem borer and wire-worm								100 plant sample for larval damage	presence or absence
European corn borer • 2 generation strain • 1 generation strain								pheromone traps sample for egg masses and leaf feeding damage on 100 plants or sequential sampling. See factsheet *European corn borer in sweet corn and other horticultural crops*	5% egg masses or damaged leaves
Corn earworm								pheromone traps	time spray by trap catch and temperature
Fall armyworm								pheromone traps 100-plant sample for larvae or leaf feeding damage	whorl stage — 15% damage tassel + silk stage — 5% damage
Corn leaf aphid								general observation	>20 aphids on 10% of ears
Corn flea beetle								count beetles on 100-plant sample	6 per 100 plants (wilt susceptible) 2 per plant (wilt tolerant)
Sap beetle								general observation	none
Corn rootworm beetles								100 plant sample, especially silk area	presence or absence

Main period of pest activity ▬▬
Pest may present at low level ——

Pheromone traps

Pheromone traps (Plates 1 and 2) are a quick and easy way of telling when a certain insect is active and what the relative population is. The traps are baited with a pheromone lure, which attracts male moths by mimicking the scent of the female. Since pheromone traps only catch males, they have no effect on controlling the pest. For corn earworms, the traps are used to determine the frequency of sprays for control. For European corn borers and fall armyworms, the traps merely indicate when it is time to scout a field. Table 7. *Traps for Sweet Corn Insects*, lists the traps recommended for the three major insect pests.

Pheromone lures should be stored in a refrigerator or freezer. If you are trapping for more than one species, avoid contaminating one lure with the

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Table 7. Traps for sweet corn insects

Insect	Trap type	Trap location	Check trap	Pheromone type	Start trapping	Replace pheromone after
European corn borer	Heliothis	grassy area near corn	twice a week	European corn borer IOWA strain	when earliest corn reaches late whorl	1 week
Corn earworm	Heliothis	in or near corn with fresh silk	twice a week	corn earworm	mid July	2 weeks
Fall armyworm	Unitrap	in or near corn	twice a week	fall armyworm	mid July	2 weeks

scent from another species. Handle lures with tweezers or rubber gloves, or wash your hands between species. Heliothis traps can be used for corn borers or earworm, and the trap picks up some of the pheromone scent over the season. Label each trap and use it for the same species year after year.

Order traps and pheromones from

Great Lakes IPM
10220 Church Rd., NE, Vestaburg, MI 48891
phone (517) 268-5693 or 5911
fax (517) 268-5311
e-mail: glipm@nethawk.com

Gempler's
100 Countryside Dr., P.O. Box 270, Belleville WI 53508
phone 1-800-382-8473
fax 1-800-551-1128
web site: www.gemplers.com

Field scouting

Field scouting is most effective for European corn borers, although regular field walks also tell you what other insects, diseases and beneficials are active. When scouting, look closely at 100 plants, making sure you walk to all representative areas of the field. One method that works well is to look at 20 groups of 5 plants selected at random while walking in a "V" or diamond pattern across a field. Try to ensure that you inspect some of the edge, centre, low spots, high spots, etc.

Scouting should begin shortly after the plants emerge to check for early season insects, 3–5 leaf dieback and weeds. It should proceed weekly until harvest, although the focus will switch to other pests as the season progresses. In the month before harvest, it may be helpful to scout twice a week to achieve optimum timing of insecticide sprays.

Harvest assessment

Harvest assessments are carried out to determine how successful a pest management program has been and how improvements can be made. The assessment should be done in the field during harvest or 1–2 days before. Harvested corn that has already been graded once by pickers does not give a true picture of damage levels.

Walk through the field as for scouting, and select 5 ears from each of 20 sites. Husk each ear, checking for the presence of insects, frass (insect droppings) or feeding damage. Identify the cause of each damaged ear and record damage levels for each pest on a harvest assessment form, as in Figure 1 on page 19. Comparing harvest assessments from fields with different spray programs helps determine the optimum pest management program.

While 100 ears is the standard sample size for most fields, this can be reduced to 50 ears for fields of less than 0.25 ha (0.6 ac). Similarly, a more complete assessment could be done on a large field (>5 ha) using 200 ears.

Insect pests

European Corn Borer

Ontario has two strains of corn borers, bivoltine and univoltine. In the southwestern counties of Essex, Kent and Elgin, the bivoltine strain completes two generations in most summers and can go on to a partial third generation in unusually warm years. In the rest of the province, the univoltine strain normally completes only one generation per year, but may begin a second in warm years. Both strains exist in significant numbers in a broad area of overlap, including Lambton, Middlesex, Oxford, Brant, Haldimand-Norfolk,

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FIGURE 1. Sweet corn harvest assessment form

Grower	Size of planting
County	Variety
Date planted	Date of assessment
Expected harvest date	
Spray history	

	Date	Product	Rate	Crop stage
1				
2				
3				
4				
5				

Insecticides applied based on (check one):_____ calendar

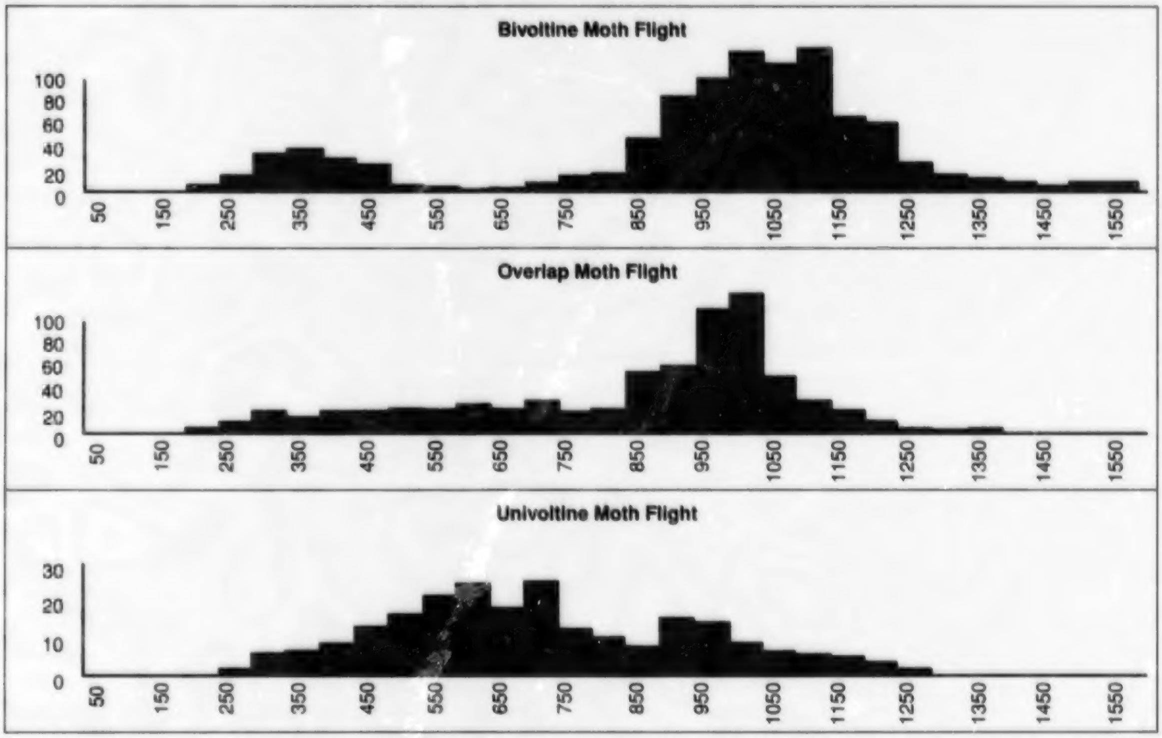
_____monitoring

Number of ears examined ________			
	Damaged ears	Damage elsewhere on plant	Total damage
European corn borer			
Corn earworm			
Fall armyworm			
Aphids			
Sap beetles			
Smut			
Other pests			
Total			

Hamilton-Wentworth and Niagara Counties. The graphs in Figure 2. *European corn borer flight.* show European corn borer flight in three regions of Ontario.

The bivoltine and univoltine moths appear identical, are attracted to the same pheromone lure, and respond to control measures in the same way. They differ in their response to temperature and day length. Under similar environmental conditions, the bivoltine strain emerges earlier in the spring and enters diapause (the inactive over-wintering stage) later in the summer or fall. The risk of crop damage and the timing of control strategies for corn borers depends partly on which strain is present.

FIGURE 2. European corn borer flight



Graph shows European corn borer flight in three regions in Ontario, averaged over 6 years (1981–86). Moth flight is related to degree days rather than date. This enables comparison between warm and cool seasons.

Biology

The corn borer has four stages in its life cycle: adult (moth), egg, larva (caterpillar), and pupa. The winter is spent as a fully grown caterpillar in or near last year's host plant. In the spring, the corn borer caterpillar changes to a pupa in its over-wintering site and a few weeks later emerges as an adult moth. While emergence begins around the third week of May in the southern-most part of the province, moths do not usually appear until mid-June in eastern Ontario.

Corn borer moths (Plate 3) are 1.5–2 cm (0.6–0.8 in.) long and about 1 cm (0.4 in.) wide when the wings are folded at rest. Their colour varies from pale yellowish brown to medium grey. The forewings have wavy dark lines running across them. Males have darker wings and are a little smaller than females.

Corn borer eggs are laid in a creamy white mass that resembles overlapping fish scales. In hot weather, eggs may hatch in as little as 3 days, but in cooler weather they may take up to 9 days. Each viable egg develops a black centre (blackhead stage) about 1 day before hatching (Plate 4).

The larvae (caterpillars) that hatch from eggs are about 3 mm (0.13 in.) long with a dark head and a spotted, dirty white body. They go through five instars (growth stages), and reach a total length of about 2.5 cm (1 in.) when fully grown. Larval colour may vary from pale greyish brown to dirty white or pale pink; head capsules range in colour from medium to dark brown (Plate 5).

Monitoring

Control strategies for the European corn borer are most effective when timed to the most sensitive stage in the insect's life cycle. Traps that catch moths are used to determine when peak flights occur and when egg laying will occur.

Corn borer moths can be trapped using a Heliothis trap baited with a pheromone lure. Traps should be set up in unmowed grassy areas near corn fields. In all parts of Ontario, corn borers are attracted to the "Iowa strain" of lure. Check traps once or twice a week and replace lures weekly.

Damage

Sweet corn is susceptible to corn borer damage from late whorl until harvest. Although the borers feed on all above-ground parts of the plant, the greatest economic damage occurs when borers feed on the ears (Plate 6). They may enter the ear through the tip, shank or husk and cause extensive feeding damage to the kernels. Ears infested with caterpillars or their frass (droppings) or ears with damaged kernels are unmarketable.

A corn borer-infested field may also attract blackbirds, initially searching for insects, but later damaging the corn.

Non-chemical control

Fortunately, natural factors kill most corn borers. Heavy rain drowns small larvae, and very dry weather desiccates them. Many eggs and small larvae are eaten by predatory insects. Several parasites attack corn borers in the fall and increase over-wintering mortality. Unfortunately, beneficial insects do not usually achieve control of corn borers.

It may also be possible to manage corn borers by releasing tiny wasps called *Trichogramma* into the field several times during the season. The *Trichogramma* become parasites on the corn borer eggs and prevent them from hatching. The wasps are harmless to humans. Of the several species of *Trichogramma* commercially available, *Trichogramma brassicae* and *T. evanescens* are most effective. (Also see "Beneficial Insects" on page 30.)

Chemical control

When pheromone traps indicate that corn borer moths are flying, growers should begin to scout fields to help time insecticide sprays. Spraying according to results of weekly or twice-weekly scouting ensures optimal use of sprays. Field trials have shown that scouted fields require fewer sprays to achieve a similar level of control as calendar-sprayed fields. While many growers may choose to scout their own fields, consultants also offer this service in some parts of the province.

When scouting your fields, look for egg masses, small caterpillars or feeding damage on the corn plants. Corn borer egg masses are usually found on the undersides of the leaves, near the midrib. Since most egg masses are laid on the central part of the plant, examine three leaves above and three leaves below the ear. Look for small caterpillars on the leaves, in leaf axils or in the silks. Feeding damage may be found

- on the leaves as window panes or shot holes
- as broken tassels
- as ear or husk damage.

Insect-resistant sweet corn

Using genetic engineering, scientists have recently developed sweet corn varieties with genetic resistance to certain caterpillar pests. A gene from a soil bacterium called *Bacillus thuringiensis* (Bt) has been incorporated into corn plants, enabling them to produce a protein that causes the insects to stop feeding and die. In the field, these "Bt-sweet corn" varieties give complete control of European corn borers and partial control of corn earworms and fall armyworms, nearly eliminating the need for sprays. The effect is targeted to caterpillars only, and the protein is harmless to humans, wildlife and most other insects.

Corn Earworm

Corn earworms are a major pest of late season sweet corn. They feed almost exclusively at the tip of the ears, leaving no visible damage on the husks or leaves.

They do not overwinter in Ontario, but fly in from the southern U.S. each summer. Usually they arrive in Ontario in August, but they may come as early as late June. Earworms are generally worse in the counties bordering Lake Erie and Lake Ontario. In some years, parts of the province may have no earworms at all.

Biology

The corn earworm adult (Plate 7) is a buff or tan-coloured moth with a wingspread of 3.5–4 cm (1.25–1.5 in.) The forewing may have several darker markings and always has a central brown dot, clearly visible on the underside of the wing and faintly visible from the top. The hindwings are very pale, with a darker brown border.

The moths lay most of their eggs individually on fresh silks. They are very difficult to see. They hatch in 2–10 days. Upon hatching, young earworms crawl down the silks toward the ear. After feeding on the silks inside the husk for a few days, they begin feeding on the kernels at the ear tip. The worms will grow up to 3.7 cm long (1.5 in.), with prominent stripes running the length of their bodies (Plate 8). The size and the presence of stripes differentiate earworms from European corn borers, while their tan head colour differentiates them from fall armyworms.

Damage

When corn earworms are present, all sweet corn with exposed fresh silk is susceptible to damage. Where sequential plantings are located close together, the field with the most fresh silk will likely receive the bulk of the egg-laying. Other fields, however, are not immune.

Earworms normally feed only on the kernels of sweet corn, beginning by feeding at the tip of the ear and moving down the ear as they grow. Feeding is almost always confined to the top third of the ear. Fecal matter is found as large moist pellets in the silk channel and at the ear tip. Earworms do not bore into the cob, as European corn borers and fall armyworms sometimes do.

Although earworms damage only a small percentage of the kernels, their presence and droppings are distasteful to most consumers. Where control has been less than perfect in the field, growers are forced to check ears at harvest and cull the damaged ones. Earworm-infested ears can sometimes still be marketed if the tips are cut off, although this practice significantly reduces the shelf life of the corn. Sweet corn destined for the processing plant may be able to sustain some earworm damage at the ear tips, as the tips are not used in the finished product.

In addition to direct damage, earworms can predispose the crop to attack by other pests. Sap beetles are attracted to the smell of fermenting sugars after earworms begin feeding.

Monitoring

The biology of the corn earworm makes it a very good candidate for an on-farm insect-monitoring program. The pest is present only at certain times, its distribution is sporadic, and a cheap, effective monitoring method gives growers enough time to implement a control program once they see the pest.

Corn earworms are monitored using a Heliothis trap, baited with a pheromone lure. Sweet corn growers should use at least two Heliothis traps to monitor for earworms. Place one trap per field in the two corn fields that are farthest apart. If two traps are used in a single field, place them at opposite ends. Move traps as often as necessary to ensure that each trap is always next to a field with fresh silk. Set up traps in mid July, then check them twice a week.

Most years, the first earworms are not trapped until August. After the first earworms arrive, check the traps three times a week. Continue monitoring until the last planting no longer has any fresh silk showing.

Control

Those who want to avoid earworm damage without the use of insecticides must plant early. Sweet corn harvested before the middle of August is usually free of earworms. After that, insecticides are necessary.

Corn earworms can be controlled with insecticide sprays applied every 3–7 days while fresh silks are present. For best results, sprays should be based on trap counts and temperature. (See Table 8. for spray intervals.) Spray intervals can be shortened as the temperature increases because unexposed silks grow faster and insecticides break down more rapidly.

The choice of insecticide is important in controlling earworms, which have developed resistance to some insecticides in the carbamate family such as Sevin and Furadan. They can be controlled by synthetic pyrethroids. Currently available products are listed in the OMAFRA publication *Vegetable Production Recommendations*, Order No. 363.

Table 8. Spray intervals for corn earworm

	Daily Maximum Temperature	
Moths/trap/week	Less than 27°C Spray every	More than 27°C Spray every
1–6	5–7 days	5–7 days
7–90	5 days	4 days
more than 90	4 days	3 days
Source: Univ. of Massachusetts Co-operative Extension		

Fall Armyworm

Fall armyworms do not overwinter in Ontario, but migrate from the southern U.S. The moths usually arrive in late July or August, with the majority of the damage occurring in September.

Biology

Fall armyworm moths have a wingspan of about 3.6 cm (1.5 in.). The front wings are dark grey with mottled whitish areas, and the males have a diagonal white slash on each wing. (Plate 9) Moths lay masses of eggs on corn leaves and cover them with beige hairs.

The caterpillars are grey-brown in colour, with stripes along the length of the body. They grow up to 3.7 cm (1.5 in.) in length. The head capsule is dark brown, with a distinct white inverted "Y" on the face (Plate 10).

Damage

Caterpillars feed extensively on the leaves of the corn plant, often destroying several leaves on one or two adjacent plants. Feeding damage consists of large holes, usually eaten in from the leaf margin. Large moist pellets of frass (droppings) are often present on the leaves or in the whorl. When fall armyworms attack corn ears, they usually enter through the side of the husk and eat in a circle around the cob (Plate 11). Fall armyworm damage is usually easy to recognize and cull out at harvest.

Monitoring

Fall armyworms damage is easily detected while scouting for European corn borers. Armyworms are usually controlled very well by spray programs aimed at corn borers and corn earworms. Most farms will not need a special monitoring program. However, if this pest has been a major problem in the past, it may be worthwhile to monitor specifically for them.

The most effective traps for fall armyworms are plastic bucket Unitraps, baited with a fall armyworm lure. Place one trap per field on a post at the field edge. Male moths are attracted to the lure and fall down a funnel to get trapped inside. It may help to add a small piece of a Vapona insecticide strip to the bucket to kill moths quickly so they remain intact for easy identification. Traps should be checked at least once a week and lures changed every 2 weeks.

Control

Like corn earworms, fall armyworms are not controlled by insecticides in the carbamate family, which are commonly used for European corn borer. They can be controlled by pyrethroid insecticides. Currently registered products are listed in OMAFRA publication *Vegetable Production Recommendations*, Order No. 363.

Aphids

The corn leaf aphid is bluish green and is the most common aphid found on corn plants. It does not overwinter in Canada, but is blown in on winds during the summer. Like other aphids, populations of corn leaf aphids are able to build to high levels rapidly, especially in hot, dry weather.

Damage

Corn leaf aphids feed on the tassels, cobs and upper leaves of corn plants (Plate 12). Their suck-

ing weakens the plant and may reduce pollination. In Ontario this has only been a significant problem on a few varieties, when high aphid populations have been present during drought conditions. Aphids also secrete a sticky substance called honeydew, in which a black fungus growth may develop. The main reason for controlling aphids is to limit the cosmetic damage caused by their presence and blackened honeydew on the cobs.

There is evidence that honeydew can attract corn earworm moths. These aphids can also carry maize dwarf mosaic virus, but so far this has not been a problem in Ontario.

Aphids are most likely to build up in hot, dry weather. Observations within Ontario show a large difference in susceptibility among sweet corn cultivars. In general, sh2 cultivars (supersweet) are likely to experience more damage than su (normal) or se (sugar enhanced) cultivars. However, there is also considerable difference among the sh2 cultivars.

Natural controls

Several types of predators and parasites attack aphids. These natural enemies include

- predators: ladybird beetles, adults and larvae; lacewings, adults and larvae; syrphid (hover) fly larvae; cecidomyiid larvae (aphid midges)
- parasites: the parasites themselves are seldom seen, but evidence of their activity, aphid mummies, is common. The mummies are two to three times the size of normal aphids and look like brown papery shells of aphids, with the exit hole of the parasite sometimes visible.

The presence of predators will often provide sufficient aphid control. However, the repeated use of broad-spectrum insecticides may wipe out natural predators, causing aphid populations to build to damaging levels. (Also see "Beneficial Insects" on page 30.)

Chemical control

In whorl stage corn, aphid control is not necessary. It may become necessary in tasselling and silking corn if the aphids threaten to make the ears unmarketable. When scouting, check the developing ears for evidence of aphids or honeydew. Count any ear with 20 or more aphids as infested. If 5%–10% of the ears are infested, a spray may be necessary.

Corn Rootworms

Two species of corn rootworm damage sweet corn. Both are beetles about 6 mm (0.25 in.) long. The northern corn rootworm is light green (Plate 13), while the western corn rootworm is yellow with black stripes (Plate 15). Damage is caused by larvae feeding on the roots and by adults feeding on the silks.

Corn rootworm beetles lay most of their eggs in corn fields in the late summer. These eggs hatch in the spring and if corn is present in the field again, the larvae feed on the roots, weakening the plants and sometimes causing lodging. Crop rotation nearly always prevents this problem. If rotation is not possible, an insecticide may be applied to the soil at planting. See OMAFRA publication *Field Crop Recommendations*, Order No. 296 for a list of currently registered products.

Silk feeding by the beetles usually begins in August and continues into the fall. It only affects sweet corn yield if heavy feeding damages the silks before pollination. If the silks are severely damaged or pruned, the ear does not pollinate fully and will be partially barren (Plate 15). In most cases, sweet corn fields pollinate before beetle populations become too heavy, or beetles are controlled by insecticide sprays applied for other pests.

Early season insect pests

Several insects can attack sweet corn seed or seedlings shortly after planting causing symptoms such as poor emergence, slow growth, wilting or seedling death. It is important to identify the specific insects causing the damage to determine the appropriate control measures. Table 9. *Early season insect pests* describes these pests and their damage.

In severe cases, it may be necessary to replant portions of a field.

Corn flea beetles

Flea beetles are shiny black beetles [2 mm (0.08 in.)] that jump rapidly when disturbed. They emerge early in the year and begin to feed on corn seedlings, causing elongated scratches on the leaves (Plate 18). Their feeding damage is

Table 9. Early season insect pests

Name	Description	Damage	Control
Potato stem borer (PSB) Hop vine borer (HVB) Plate 16	pinkish caterpillar up to 35 mm long (1.4 in.), found inside plant below growing point dirty white caterpillar with purple bands, up to 35 mm long (1.4 in.), found inside plant below growing point	similar for PSB and HVB - enters seedling to early whorl corn plants below soil and tunnels upward; upper leaves wilt but lower leaves remain healthy; damage most severe at field edges or in areas that were weedy last fall	No control for existing infestation; good weed control will reduce future damage
Cutworms Plate 17	dark grey caterpillar up to 50 mm long (2 in.), found in soil, often close to damaged plants	cuts seedling off at ground level; one cutworm may cut several plants;	insecticide banded over the row; see "General Pests" section of OMAFRA Publication 363
Wireworms	hard, shiny, yellow-brown larva, up to 30 mm long (1.2 in.), found in soil	wireworms tunnel into seed or roots of seedling, killing or weakening plants; most severe within 2 years after sod	avoid planting within 2 years of sod; use insecticide seed treatment
Seedcorn maggot	white legless maggot, up to 5 mm long (1/5 in.), found inside seed	maggot feeds inside germinating seed, weakening plant and allowing disease entry	use seed treatment with insecticide and fungicide

rarely serious, but they can carry the bacteria that cause Stewart's wilt (See "Stewart's wilt" on page 27.) This disease shows up as irregular yellow or light green streaks on the leaves, either in the whorl stage or after tasselling. In severe cases, seedlings wilt and die.

Flea beetles are rarely a problem in Ontario, as most do not survive the winter. Higher populations are found after mild winters, and this increases the risk of transmitting the bacteria that cause Stewart's wilt. The first generation of the beetles, in May and June, is the most likely to cause damage. When subsequent generations are active, from July until frost, the corn plants are not as susceptible.

Sweet corn hybrids vary from resistant to highly susceptible to Stewart's wilt. There is no control for the disease, but it can be prevented by controlling the beetles. Where flea beetles are found on susceptible hybrids, insecticides may be applied to control them.

Diseases

3–5 leaf dieback

Three–5 leaf dieback is often a problem when supersweet (sh2) hybrids are planted in cold soils, although it may also occur with other hybrids.

Biology

Super sweet corn cultivars with the sh2 gene are most susceptible. The shrunken and shriveled kernels of these cultivars, particularly if they are damaged or cracked, are readily infected by Penicillium, Pythium and Fusarium. These fungi are common in soil and on plant debris. Penicillium and Fusarium spores usually get onto kernels during harvest, and the fungi continue to colonize the kernels during storage. Pythium does not colonize stored seed but is present in most soils. Three–5 leaf dieback is most severe when infected kernels are planted in cold (<14°C or 57°F), wet soils during the spring.

Damage

Symptoms of this disease are similar to damping-off caused by other soil-borne fungi. It is most frequently associated with *Penicillium oxalicum*, although other fungi have been implicated as causal agents. Seeds either rot and fail to emerge or seedlings appear weak, stunted and yellow with brown lesions on the subcrown internode and root. The result is a poor plant stand (Plate 19) and low yields. Damage from early season insect pests such as seed corn maggot and wireworm may also cause these symptoms and encourage further colonization of germinating seed by the fungi.

Monitoring

Sweet corn fields should be monitored twice a week for the first few weeks after planting, especially if soils are cold and wet. Dig up a few seeds to check for germination, and look for any discolouration or rotting. As the plants emerge, check

the stand for evenness and investigate any areas of poor emergence.

Control
There is no rescue treatment for seedlings that are affected with 3–5 leaf dieback. Disease control depends on prevention. The risk of the disease can be greatly reduced by preventing damage to kernels when handling them during harvest and prior to storage. Seed for supersweet hybrids must be handled with care, as any damage to the shrunken seeds allows disease-causing fungi to colonize the kernals.

Planting high quality seed, treating seed with a fungicide and avoiding excessively deep planting helps reduce infection. Delaying planting until the soil has warmed to favour rapid germination and emergence significantly reduces the risk of disease.

Common Rust
Common rust is often a late-season disease on sweet corn and has become more prevalent in recent years. Increased production of winter corn in the southern United States and new strains of the fungus capable of overcoming the genetic resistance bred into resistant sweet corn lines may be contributing to the increased incidence and earlier arrival of this disease in Ontario.

It is characterized by reddish-brown pustules or blisters on the leaves that break open to release rust-coloured spores (Plate 20). The pustules turn black late in the season with the production of teliospores. If severe, it can reduce yields by reducing leaf photosynthesis and plant vigour. In addition, rust on the husks will downgrade the marketability of the ears.

Biology
The biology and life cycle of corn leaf rust is complex. Dark teliospores or winter spores overwinter in the soil in the southern U. S. In the spring the winter spores germinate to produce a spore that is only capable of infecting wood sorrel. Sexual reproduction occurs on the wood sorrel, resulting in the production of spores that are carried by wind to corn. These spores infect only corn tissue, resulting in the production of the reddish brown uridiniospore or "summer spore" in pustules. The summer spores can be blown or splashed by rain to other corn tissue through the remaining growing season, and the summer disease cycle repeats until the corn tissue begins to senesce.

Disease development is favoured by cool weather (16–23°C or 61–73°F) and environmental conditions that result in dews during the night. In the late summer, the pustules produce the dark brown winter spores.

Although wood sorrel is an alternative host for corn leaf rust, it does not significantly contribute to corn leaf rust epidemics in Ontario. The severity of rust epidemics in Ontario is partly determined by the volume of spores and the time of arrival from the U.S. Most spores blow in from corn-growing regions in the southern United States arrive too late in the growing season to cause significant yield losses in Ontario. However, early arrival of corn leaf rust can result in significant yield losses.

Monitoring
Fields should be monitored for corn leaf rust during insect scouting.

Control
Early planting of sweet corn usually avoids significant damage by corn leaf rust. There is a broad range of susceptibility to rust among sweet corn hybrids. Seed companies routinely evaluate new hybrids for rust resistance and have records of susceptibility for most older hybrids. Planting resistant varieties, particularly in areas such as Essex and Kent counties that are more prone to the early arrival of leaf rust, reduces the risk of yield loss should the disease arrive early.

If rust becomes a problem in individual fields, it can be controlled with foliar fungicides. See the OMAFRA publication *Vegetable Production Recommendations*, Order No. 363, for a list of products.

Common Smut
Common smut is a grotesque disease of sweet corn that is present every year in Ontario. The disease usually does not result in economic losses. However, under favourable conditions, the disease can result in reduced marketable yields.

Biology
Common smut produces smooth pale grey galls on the ears, leaves or tassels of corn plants (Plate 21). These galls contain masses of black spores

that are released when the galls rupture. Wind carries the spores to other parts, plants and fields. Spores germinate on the surface of the plant tissue and infect directly or, more frequently, through wounded tissue. Wind, hail and insect damage frequently predispose the plant to common smut infection. Hot and dry environmental conditions favour disease development. The spores are weather resistant and can survive for many years in soil and crop debris. During the spring, the spores germinate to produce secondary spores capable of infecting the rapidly growing tissue of corn seedlings. Infected young tissue develops into galls that rupture and release the black spores that infect other plants all summer long.

Monitoring

Fields should be monitored for common smut during insect scouting. Infected plants should be pulled and carried out of the field in plastic bags.

Control

Many sweet corn hybrids carry some level of resistance to smut, but none is immune. Seed treatments, foliar fungicides and crop rotation are not effective in controlling smut. The best way to minimize the level of smut in a field is to ensure the plants have good growing conditions and are free from stress. Avoiding mechanical damage to plants during cultivation reduces the risk of smut infection. Sweet corn fields should be scouted for this disease if damage to the field has occurred from insects, wind or hail.

Head Smut

Head smut is a disease of sweet corn not frequently observed in Ontario. However, this disease did cause significant losses in 1979. The symptoms of the disease are often not noticed until plants begin to produce tassels.

Biology

The disease is caused by a fungus that can be both seed and soil borne. Spores can persist in soil for more than 10 years. During the spring, dark brown spores germinate in the soil or on the surface of contaminated seed coats and infect seedlings.

Damage

Unlike common smut, the fungus does not produce galls, but grows throughout the developing plant. Infected plants eventually produce wire-brush like tassels with short branches covered with black sooty spores. Frequently, leaf-like tissue is seen growing out of the tassel. Infected plants produce stubby ears without silks that are spongy when squeezed. Pealing back the husks of ears on infected plants reveals a mass of dark reddish brown-to-black spores. During harvest, the spores contaminate kernels, machinery and soil.

Monitoring

Fields should be monitored for head smut soon after tassel emergence. Fields with infected plants should be harvested last to prevent the spread of the disease by contaminated equipment.

Control

Disinfecting machinery before moving from infected to uncontaminated fields reduces the spread of the disease. Crop rotation, planting sweet corn varieties resistant to this disease and using fungicide seed treatments significantly reduce the potential of disease infection.

Stewart's wilt

Stewart's wilt is caused by bacteria (*Erwinia stewartii*). Historically, it has not been a significant problem in Ontario. Harsh winter conditions generally wipe out most of the corn flea beetles, which are the primary vectors of this disease. However, when mild winter conditions allow for increased beetle survival, Stewart's wilt can become a much bigger concern.

Biology

The bacteria overwinter in the gut of the corn flea beetle and on infested seed. They cannot survive the winter in infected crop debris left on the soil surface. The disease is usually transmitted from the corn flea beetles to corn plants during feeding. If seedlings get infected, significant damage can occur.

Damage

Early infection of sweet corn seedlings causes plants to appear wilted and stunted. Severe infections result in seedling death. Plants infected later in the season have blight symptoms on leaves. Pale green to yellow lesions running parallel to the leaf veins may extend the entire length of the leaf, frequently with irregular margins (Plate 22). Older leaves appear to be

scorched and can be confused with similar symptoms caused by drought and nutrient deficiencies. When the lower stems of infected plants are cut, dark brown cavities may be observed in the rotting pith, and a bright yellow bacterial slime oozes from the vessels. The slime forms strings when touched with a knife and pulled away slowly.

Monitoring
Fields should be monitored for corn flea beetles.

Control
Controlling corn flea beetles significantly reduces the incidence and spread of this disease. Crop rotation and ploughing of corn residue also reduces the potential of the bacteria surviving in soil. Most sweet corn cultivars are susceptible to Stewart's wilt, although some sugar enhanced cultivars show resistance. Planting varieties that show resistance to Stewart's wilt, particularly in seasons following mild winters, can reduce the risk of losses to this disease.

Stalk, Ear and Kernel Rot
Several fungi, including Fusarium, Penicillium and Pythium, can cause stalk, ear and kernel rot of sweet corn. Super sweet corn cultivars with the sh2 gene are very susceptible to infection by these fungi. Although the fungi do not usually cause significant problems on kernels and ears harvested for the fresh market, they can significantly reduce the viability of kernels harvested for seed. Some fungi, such as Fusarium, can produce toxins during the colonization of kernels. This phase of the disease in sweet corn produced for the fresh market is considered unimportant. But since little research has been conducted in this area, growers should take precautions to reduce infections where possible.

Biology
Stalk rot is considered the most important phase of the diseases caused by these fungi. Infection, disease development and the severity depend on the specific fungi involved and the environmental conditions that favour disease. Stalk rots caused by *Stencarpella maydis, Fusarium moniliforme* and *F. graminearum* are favoured by warm dry conditions in the spring followed by warm wet weather after silking. Stalk rot caused by Pythium is favoured by hot wet environmental conditions, particularly on plants growing in poorly drained soil. The fungi can attack seeds, seedlings, leaves and stalk tissue. Early infection by these fungi can result in seedling blight or damping-off. These pathogens persist for many years in soil and on infected crop debris. Plants that are grown under stress caused by high plant densities, unbalanced nutrients (particularly excess nitrogen), drought, unfavourable temperatures (too hot or cold) or damaged by insects, birds, wind, hail or machinery are more prone to stalk rot.

Some of the fungi can infect ears through insect and bird damage, while others infect ears and kernels by colonizing and moving down the silk. The disease spreads by wind, rain splash and insects.

Damage
Symptoms of stalk rot vary depending on the specific fungus and usually appear late in the growing season. Sudden wilting together with dull greyish green leaves and premature senescence are frequently observed on infected plants. Infections caused by Pythium tend to be close to the soil surface and appear as water-soaked lesions that girdle the stem, frequently resulting in plant lodging. Fusarium causes the stem pith to rot, and frequently a reddish mouldy appearance is seen when the rotted stems are split. The disease can progress up and down the stem resulting in stem breakage or lodging when lower internodes become infected.

Monitoring
Monitor fields for stalk rot early in the growing season. Roguing out affected plants can reduce the spread of the disease.

Control
Crop rotation with non-cereal crops helps reduce the pathogenic fungi population in soil. Choose cultivars with stalk rot resistance. If susceptible varieties are required, reducing the plant densities can help decrease the potential spread of stalk rot pathogens from plant to plant. Follow a balanced nitrogen-to-potassium fertility program, since stalk rots tend to be more severe in the presence of excess nitrogen.

Vertebrate pests

Vertebrate pests, including raccoons, deer and birds, can cause substantial losses to sweet corn (Plate 23). The list that follows is a summary of published data from Ontario and nearby states. Not all of the possible controls listed here have been tested in Ontario.

Vertebrate control is often expensive and usually does not prevent all damage. It is a matter of trying to balance the cost of controls with the value of lost corn. The proximity of sweet corn fields to wildlife habitat is often the greatest factor in determining how much damage will occur. Deer populations tend to be higher near woodlots, and pest birds tend to congregate near marshes. Raccoons may be worse near towns or built-up areas.

Raccoons

Electric netting is an electric fence made of horizontal strands of plastic and metal twine, joined by vertical strands of plastic twine. It comes complete with posts and can be moved from one field to another.

Home made electric fences are sometimes used. Two strands, at 5 cm (2 in.) and 12 cm (4.7 in.) height above ground that is kept weed-free are usually effective against raccoons.

Trapping can be effective if it is started about a week before the corn enters the silk stage and continued throughout the harvest season. Check with your local Ministry of Natural Resources office for permits before trapping.

Deer

Electric netting is also available for deer.

Home made electric fences can be used. A single strand of wire at about 75 cm (30 in.) in height may be effective, but a multiple wire fence about 2 m (6.5 ft) high may be needed where high deer populations exist.

Invisible fencing consists of an underground wire around a field border. Dogs are trained to stay within the borders and chase wildlife out.

Hinder is a chemical repellent for deer that is sprayed on crops. It lasts 2–4 weeks, but needs to be reapplied after rain.

Contact the Ministry of Natural Resources for information on shooting deer on your own property or arranging for hunters to do so. Hunting during the regular season reduces the population in the area for the sweet corn season.

Noisemakers such as Av-alarms, propane cannons or horns harass deer and reduce their damage, but probably do not eliminate it. Motion-activated devices may be more effective than devices that are operated continuously.

Birds

Red-winged blackbirds cause most of the damage in corn fields. They nest in wet areas, and corn adjacent to these areas suffers the worst damage. Avoid planting fields near marshy areas to late corn when the risk of bird damage is greatest.

Choosing sweet corn varieties with a tight husk, thick tip, good tip cover and narrow cob angle (cob almost vertical) reduces but does not eliminate bird damage.

Some birds are initially attracted to fields by insects or weeds, then switch to sweet corn as other food sources decline. Keeping fields weed-free and minimizing insect damage may prevent some bird damage.

Birds will often leave standing corn alone if easier food is available. Providing food by flattening the rows of early corn after harvest can reduce bird damage in currently harvested sweet corn.

Avitrol is a toxic bait that kills a few birds and scares others away with their distress calls. A permit must be obtained from the Ministry of Environment for each use.

Noisemakers, such as Av-alarms, propane cannons, exploding shotgun shells, the Phoenix Wailer and recordings of bird distress calls are sometimes used. They are most effective if more than one technique is used and if their use pattern is changed frequently so that birds don't get used to them.

Visual frightening devices such as scare balloons and bird scare tape can reduce bird damage. Like noisemakers, they should be combined with other methods and their location changed frequently.

The presence of hawks or owls deters many bird pests from crop fields. Birds of prey can be encouraged by erecting suitable lookout posts in or near the field or by building nesting boxes at woodlot edges.

Beneficial insects

Several beneficial insects are active in sweet corn fields. These help reduce the level of pests and their damage. They are most effective against indirect pests such as aphids. Beneficial insects can be encouraged by avoiding the use of broad-spectrum insecticides. Among the insecticides currently registered for use in sweet corn, pyrethroid insecticides are the most toxic for beneficials. Carbamate insecticides (Sevin, Lannate and Furadan) are somewhat less toxic to beneficials. Organophosphate insecticides such as Orthene are less toxic than carbamates. Biological insecticides such as Dipel kill only caterpillars, so are completely non-toxic to beneficials. Bt sweet corn is also non-toxic to beneficials.

Providing refuge areas in or near fields may also encourage beneficials. These areas should have a variety of flowering plants (for nectar) and should be unsprayed, so the beneficials can forage for other insect species.

Some species of beneficials are available commercially for release in crops. Most of these (aphid midges, lacewings, ladybugs) could be useful in small plantings, but would likely prove too costly or time consuming for a large acreage. *Trichogramma* wasps however, have been used for corn borer control on large acreages, and the potential exists for that use in Ontario.

Hoverfly (*Syrphidae*)

Adult flies are about the size of a house fly and are black with yellow markings. They are often found hovering near flowers, and are common on corn tassels. The larvae are white or brown legless maggots about 1-5 mm (0.04–0.2 in.) long (Plate 24). They are found in aphid colonies, feeding on the aphids.

Lacewing (*Chrysopidae*—green lacewings; *Hemerobiidae*—brown lacewings)

Lacewing adults are green or brown insects up to 20 mm (0.7 in.) long, with large, lacy transparent wings that they hold tent-like over the body. The larvae are cream or brown and resemble alligators with large pincer jaws (Plate 25). Both adults and larvae are predacious, feeding on aphids, insect eggs, and small larvae.

Lady beetle (*Coccinellidae*)

Adults are usually red beetles with black spots, up to 8 mm long. Larvae are dark coloured, alligator-like insects up to 10 mm (0.4 in.) long, often with bright markings (Plate 26). The eggs are distinctive, being spindle-shaped and bright orange or yellow, and are usually laid in clusters on the underside of leaves. Both adults and larvae are predacious, feeding mostly on aphids, but they will also feed on eggs and small caterpillars.

Minute pirate bug (*Anthocoridae*)

These are fast-moving bugs often found in the leaf axils of corn, where they feed on pollen and all sorts of insects. Adults are black with white wing patches and are about 3 mm (0.12 in.) long (Plate 27).

Trichogramma wasps (*Trichogrammatidae*)

These tiny 0.5 mm (0.02 in.) wasps are parasites on the eggs of caterpillars. One species attacks European corn borer eggs while another attacks corn earworm eggs. Both are available commercially. *Trichogramma* are also present naturally at low levels. Parasitized corn borer egg masses turn completely black (Plate 28). In unparasitized corn borer egg masses that are close to hatching, each egg has a black centre. (Plate 4)

Refer to the following OMAFRA Factsheets for more information:

***European Corn Borer in Sweet Corn and Other Horticultural Crops*, Order No. 97-019.**

***Corn Earworm*, Order No. 95-065**

***Insects and Diseases of Sweet Corn in Ontario*, Order No. 94-027**

***Corn Rootworms*, Order No. 89-174**

***Potato Stem Borer in Ontario*, Order No. 86-030**

Visit the vegetable page on the OMAFRA web site at

http://www.gov.on.ca/omafra/english/crops/hort/vegetable.html

APPENDIX A. The Metric System

Metric Units

Linear Measures (length)

10 millimetres (mm)	=	1 centimetre (cm)
100 centimetres (cm)	=	1 metre (m)
1,000 metres	=	1 kilometre (km)

Square Measures (area)

100 m x 100 m = 10,000 m^2	=	1 hectare (ha)
100 ha	=	1 square kilometre (km^2)

Cubic Measures (volume)

Dry Measure

1,000 cubic millimetres (mm^3)	=	1 cubic centimetre (cm^3)
1,000,000 cm^3	=	1 cubic metre (m^3)

Liquid Measure

1,000 millilitres (mL)	=	1 litre (L)
100 L	=	1 hectolitre (hL)

Weight-Volume Equivalents (for water)

(1.00 kg) 1,000 grams	=	1 litre (1.00 L)
(0.50 kg) 500 grams	=	500 mL (0.50 L)
(0.10 kg) 100 grams	=	100 mL (0.10 L)
(0.01 kg) 10 grams	=	10 mL (0.01 L)
(0.001 kg) 1 gram	=	1 mL (0.001 L)

Weight Measures

1,000 milligrams (mg)	=	1 gram (g)
1,000 grams	=	1 kilogram (kg)
1,000 kilograms	=	1 tonne (t)
1 mg/kg	=	1 part per million (ppm)

Dry-Liquid Equivalents

1 cm^3	=	1 mL
1 m^3	=	1,000 L

Application Rate Conversions

Metric to Imperial (approximate)

litres per hectare x 0.09	=	gallons per acre
litres per hectare x 0.36	=	quarts per acre
litres per hectare x 0.71	=	pints per acre
millilitres per hectare x 0.015	=	fluid ounces per acre
grams per hectare x 0.015	=	ounces per acre
kilograms per hectare x 0.89	=	pounds per acre
tonnes per hectare x 0.45	=	tons per acre

Imperial to Metric (approximate)

gallons per acre x 11.23	=	litres per hectare (L/ha)
quarts per acre x 2.8	=	litres per hectare (L/ha)
pints per acre x 1.4	=	litres per hectare (L/ha)
fluid ounces per acre x 70	=	millilitres per hectare (mL/ha)
tons per acre x 2.24	=	tonnes per hectare (t/ha)
pounds per acre x 1.12	=	kilograms per hectare (kg/ha)
ounces per acre x 70	=	grams per hectare (g/ha)

Liquid Equivalents

litres/hectare		*gallons/acre (approx.)*
50	=	5
100	=	10
150	=	15
200	=	20
250	=	25
300	=	30

Dry Weight Equivalents

grams or kilograms/hectare		*ounces or pounds/acre*
100 grams	=	11/2 ounces
200 grams	=	3 ounces
300 grams	=	41/4 ounces
500 grams	=	7 ounces
700 grams	=	10 ounces
1.1 kilograms	=	1 pound
1.5 kilograms	=	1 1/4 pounds
2.0 kilograms	=	1 3/4 pounds
2.5 kilograms	=	2 1/4 pounds
3.25 kilograms	=	3 pounds
4.0 kilograms	=	3 1/2 pounds
5.0 kilograms	=	4 1/2 pounds
6.0 kilograms	=	5 1/4 pounds
7.5 kilograms	=	6 3/4 pounds
9.0 kilograms	=	8 pounds
11.0 kilograms	=	10 pounds
13.0 kilograms	=	11 1/2 pounds
15.0 kilograms	=	13 1/2 pounds

Metric Conversions

5 mL	=	1 tsp
15 mL	=	1 tbsp
28.5 mL	=	1 fl. oz

Conversion Tables — Metric to Imperial

Length

1 millimetre (mm)	=	0.04 inch
1 centimetre (cm)	=	0.40 inch
1 metre (m)	=	39.40 inches
1 metre (m)	=	3.28 feet
1 metre (m)	=	1.09 yards
1 kilometre (km)	=	0.62 mile

Area

1 square centimetre (cm^2)	=	0.16 square inch
1 square metre (m^2)	=	10.77 square feet
1 square metre (m^2)	=	1.20 square yards
1 kilometre (km^2)	=	0.39 square mile
1 hectare (ha)	=	107,636 square feet
1 hectare (ha)	=	2.5 acres

Volume (dry)

1 cubic centimetre (cm^3)	=	0.061 cubic inch
1 cubic metre (m^3)	=	1.31 cubic yards
1 cubic metre (m^3)	=	35.31 cubic feet
1,000 cubic metres (m^3)	=	0.81 acre-foot
1 hectolitre (hL)	=	2.8 bushels

Volume (liquid)

1 millimetre (mL)	=	0.035 fluid ounce
1 litre (L)	=	1.76 pints
1 litre (L)	=	0.88 quart
1 litre (L)	=	0.22 gallon (Imp.)
1 litre (L)	=	0.26 gallon (U.S.)

Weight

1 gram (g)	=	0.035 ounce
1 kilogram (kg)	=	2.21 pounds
1 tonne (t)	=	1.10 short tons
1 tonne (t)	=	2,205 pounds

Pressure

1 kilopascal (kPa)	=	0.15 pounds/in^2

Speed

1 metre per second	=	3.28 feet per second
1 metre per second	=	2.24 miles per hour
1 kilometre per hour	=	0.62 mile per hour

Temperature

°F = (°C X 9/5) + 32

Imperial to Metric (approximate)

Length

1 inch	=	2.54 cm
1 foot	=	0.30 m
1 yard	=	0.91 m
1 mile	=	1.61 km

Area

1 square foot	=	0.09 m^2
1 square yard	=	0.84 m^2
1 acre	=	0.40 ha

Volume (dry)

1 cubic yard	=	0.76 m^3
1 bushel	=	36.37 L

Volume (liquid)

1 fluid ounce (Imp.)	=	28.41 mL
1 pint (Imp.)	=	0.57 L
1 gallon (Imp.)	=	4.55 L
1 gallon (U.S.)	=	3.79 L

Weight

1 ounce	=	28.35 g
1 pound	=	453.6 g
1 ton	=	0.91 tonne

Pressure

1 pound per square inch	=	6.90 kPa

Temperature

°C = (°F – 32) X 5/9